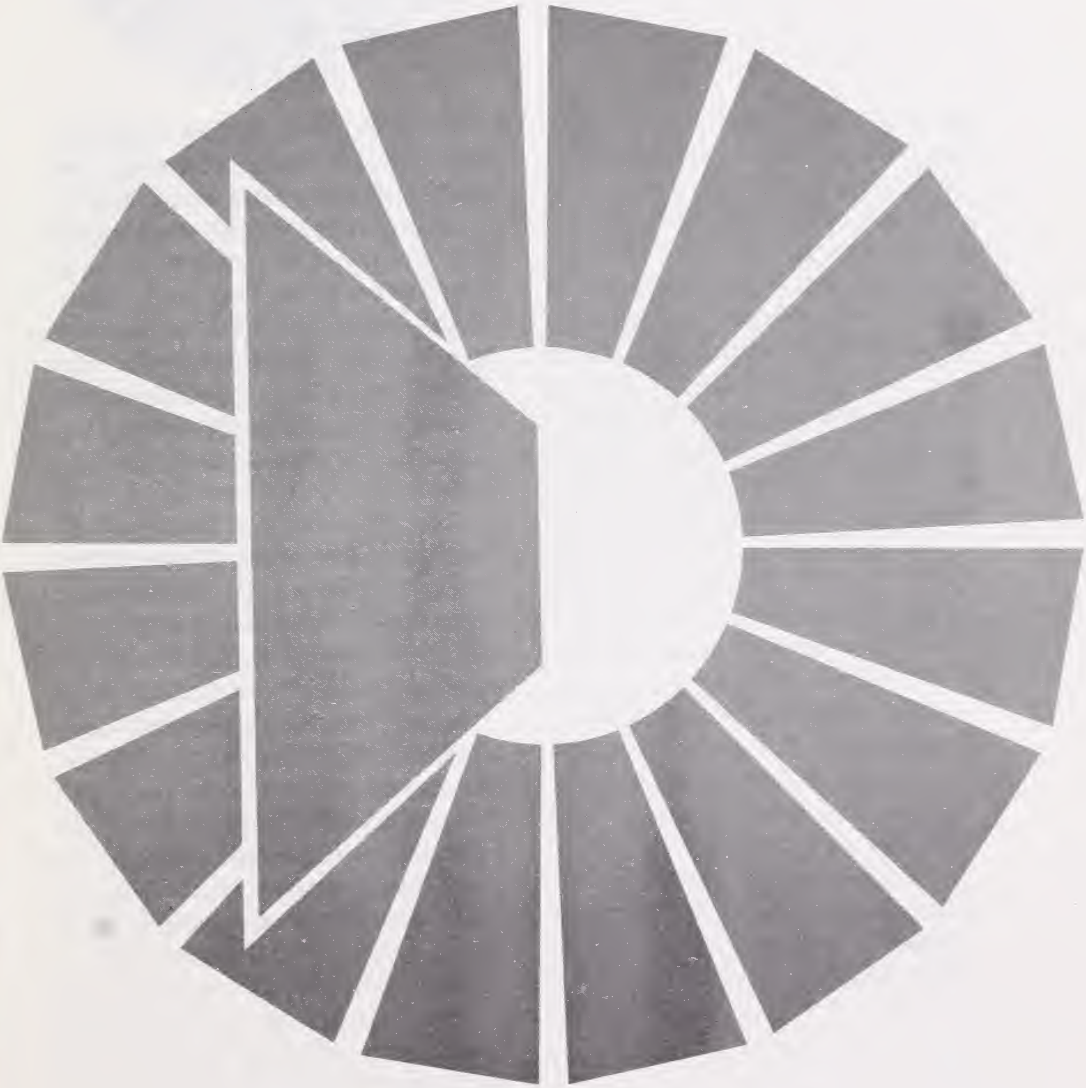
Wind Power and Windmills



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Because of the future need for alternative sources of energy, the Federal Government and many private companies are developing new wind electric generators larger than those that have been commercially available. In addition, the U.S. Department of Agriculture and several State and private universities are testing ways to use wind power economically.

The information in this publication is adapted from Windmills and Wind Generators, Leaflet 2001, by R.A. Parsons and W.C. Fairbank, Cooperative Extension Service, University of California.

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Wind Power and Windmills

Wind is a free and inexhaustible source of energy, but its use as a power source depends on the cost of equipment necessary to harness it.

The many windmills supplying water for midwestern farms, and the "wind chargers," once more common than power poles across the great plains, are largely gone now—victims of cheaper, more reliable power sources, such as the gasoline engine or electric motor.

Increased fuel costs and power shortages have renewed interest in obtaining energy from the wind, and much research in this area continues throughout the world. Large-scale, commercial use of wind power has had limited success in some countries, and wind-driven generators of up to 1,250 kilowatts (kw) capacity have been constructed.

The most successful and readily available forms of equipment have been the multibladed windmill used for pumping water, and the propellor-type, high-speed unit used to generate electricity. These small units have propellors 6 to 16 feet in diameter, depending on the power needed.

But why haven't windmills and wind generators been used more? What are some of the problems?

Windmills and wind generators have not been economical except where electricity is not otherwise available, or where engine-powered equipment cannot be attended. For example, water pumped in 1 year by a typical windmill costing $1,000 to $1,200 could be produced by a one-fourth horsepower electric motor and pump at a cost of $40 to $100 in utility electricity.

Windmills and wind generators are expensive and do not generate enough power to pay for the large investment. To be competitive with utility power, wind-powered devices should cost in the range of $2.50 to $6 per square foot of area swept by the propellor. Typical wind devices marketed today cost $15 to $55 per square foot of swept area, depending on accessories included.

Because utility power has been so inexpensive, windmills have remained in use only in remote areas where other forms of power are not available. But, with renewed interest, perhaps less expensive designs will be developed and will become more widely used in the future.

Wind is intermittent, and wind speeds vary in different areas (table 1). Reliable general purpose electric power from the wind has required a number of batteries to store energy for periods of low wind which may last a week or more. These batteries add to the investment.

TABLE 1. Examples of average wind speeds (miles per hour)

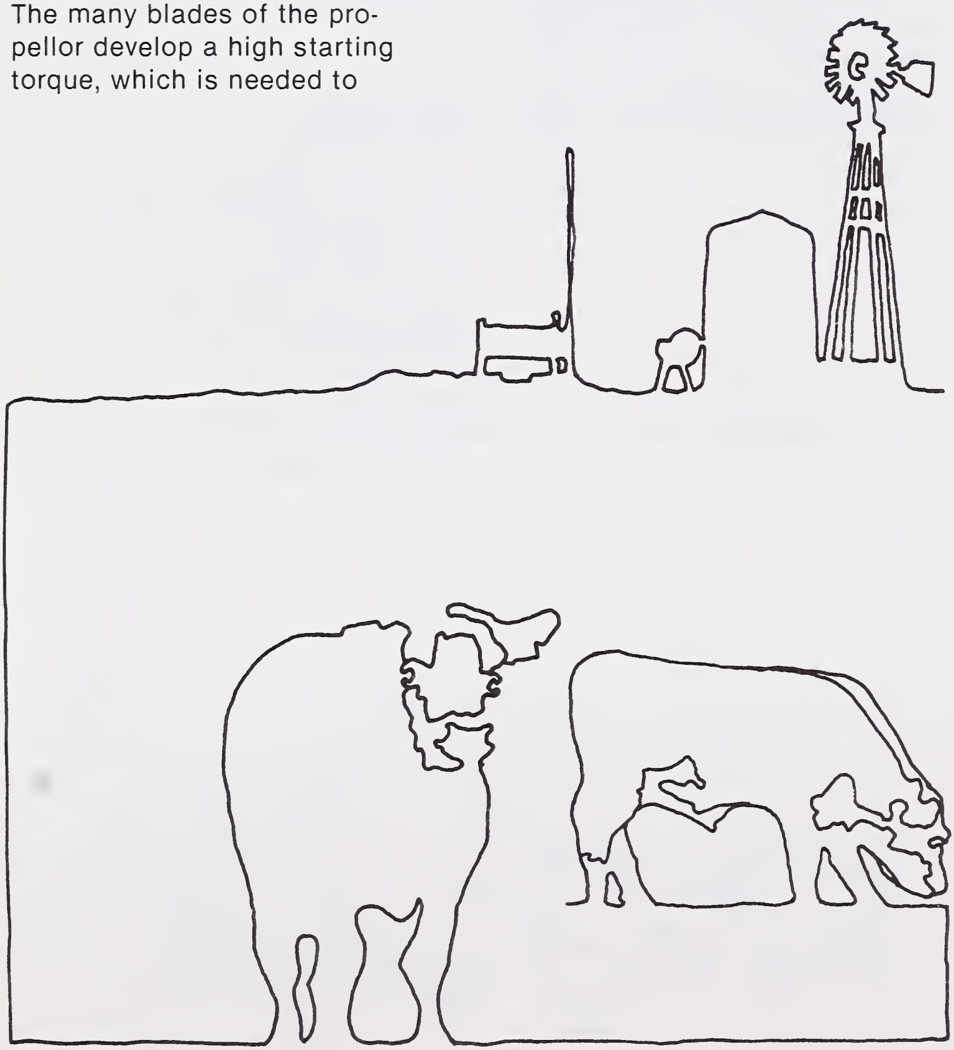
City	*April*	*October*	*Annual*
Amarillo, Tex.	15.5	13.0	13.7
Cheyenne, Wyo.	14.7	12.5	13.3
Columbus, Ga.	7.5	6.5	6.9
Des Moines, Iowa	13.3	10.5	11.1
Memphis, Tenn.	10.7	7.8	9.1
Sacramento, Calif.	9.1	6.8	8.3
Syracuse, N.Y.	11.0	9.2	9.9

Windmills for pumping water

The windmill almost everyone remembers is the multibladed type that has 15 to 40 galvanized steel fan blades and is used to pump water for the farm. The fan drives a mechanism that converts rotary motion to an up-and-down motion used to drive a piston pump.

The pump cylinder is placed in the water near the well bottom and a pump rod descending from the windmill drives it. The many blades of the propellor develop a high starting torque, which is needed to overcome the high starting load of a piston pump.

These windmills are used most commonly for supplying water for livestock at remote locations. Occasionally they are also used for irrigation of small areas, such as gardens or small orchards.



Pumping Rate

Larger mills can lift water 400 to 600 feet from a deep well to a tank. Maximum pumping capacities are shown in figure 1. These range from 100 to more than 2,000 gallons per hour, depending on the windmill diameter and height of lift or head.

The maximum pumping rate will be achieved only about 15 to 30 percent of the year. Moderate winds of 8 to 12 miles per hour blow 25 to 30 percent of the time in many areas and will run a windmill at about half its rated output. With these typical wind conditions, a 10-foot-diameter mill pumping against a 100-foot head should pump an annual average of 4,500 gallons per day, or 1.63 million gallons of water per year.

Wind speed has an important effect on pumping output. Below a certain speed the wind does not have enough power to operate the pump at all. Above this speed the pumping rate will be approximately proportional to the wind until windmill overspeed controls limit the output (figure 2).

The propellor is mounted off-center from the tower axis so it will "furl" or swing out of the main wind direction when wind speeds climb to 22 to 25 mph and above. While this furling feature protects the windmill mechanism, it also limits the pumping rate to that of a 15- to 20-mph wind, no matter how fast the wind blows.

Storage

Since the wind doesn't always blow, water should be stored for use during calm periods. The simplest storage is a stock watering tank placed on the ground beside the mill. The water from this tank can be used for irrigation or watering stock. If pressure is needed, locate the water tank on a tower near the windmill.

Figure 1.

Typical maximum pumping rates of windmills.

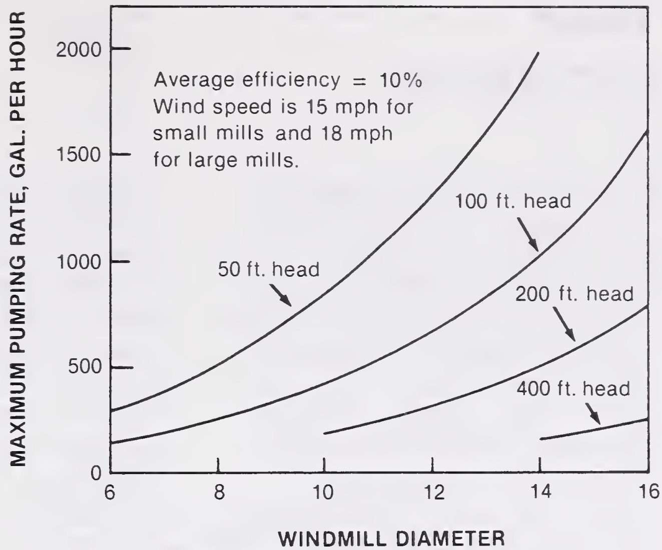
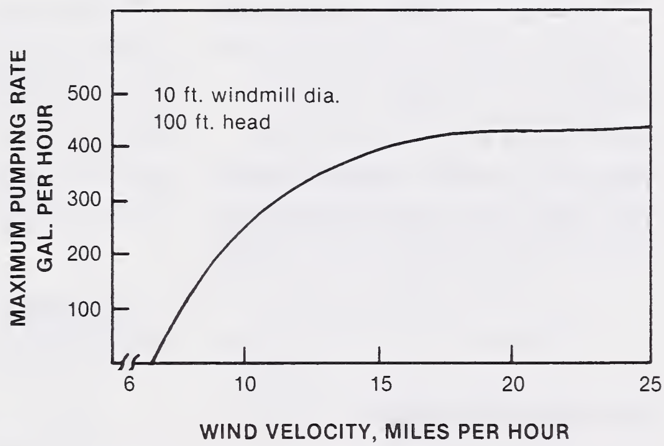


Figure 2.

Typical windmill output versus wind velocity.



Wind Generators

Wind-driven electric generators can supply power for household and farmstead use. Because most commercially available units are limited in size, use will usually be limited to lighting, refrigerator/freezers, small power tools, domestic water systems, and small appliances. Space heating and water heating require more energy than can be supplied by commercially available wind generators at present.

The most common use of wind generators is in remote areas not served by power lines, for unattended beacon lights and communications equipment, for isolated camps with minimal lighting and low-demand electrical equipment, and for recreational cabins.

Energy Output

The maximum power output or rated wattage of most wind generators is developed at wind speeds of 23 to 30 mph. Below this speed the output drops as shown in figure 3 (in proportion to the cube of the wind speed).

For example, a generator with a 16-foot-diameter propellor develops only about 150 watts in an 8-mph wind. The potential monthly kilowatt-hour (kWh) energy output will be limited in most areas because of lack of wind. For comparison, a typical household uses 400 to 600 kWh of electricity each month. A dependable, continuous-use wind system also must include storage batteries.

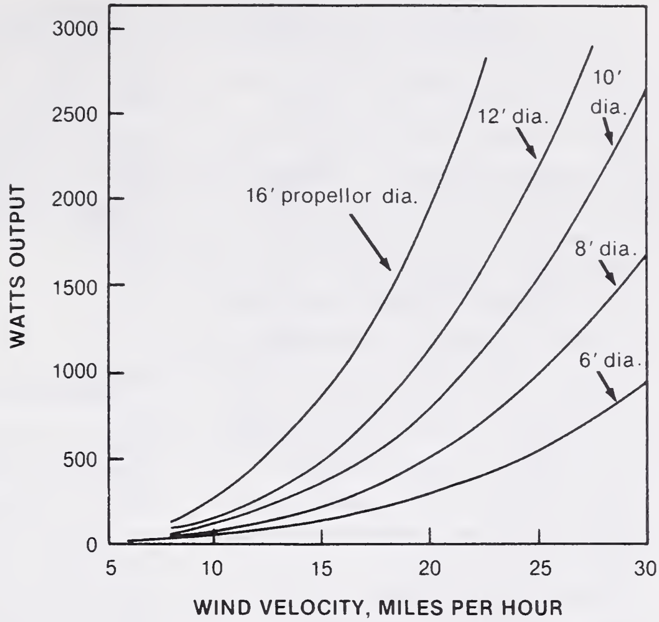
The average monthly kWh output can be estimated for any area if the average wind speed is known. Multiply the maximum rated kilowatt output of the wind generator by the factor shown for these average windspeeds:

Average windspeed, mph	*Multiplier factor*
8	30
10	50
12	80
14	110

Example: A wind generator rated at 2 kW and located in an area with an average wind speed of 10 mph would generate 100 kWh per month (2 x 50).

This system gives only a rough estimate. Actual output depends on such factors as tower, design characteristics of the generator, nearby obstructions, etc.

Figure 3.
Typical wind generator output versus wind velocity.



Wind Generator Systems

Basic components are:
—**A 2-to 4-blade propellor** that directly drives or is geared to a generator.
—**A tower** that is either free-standing or that mounts on an existing building to reach more dependable, higher speed winds above trees and other obstructions. The unit usually is mounted 40 to 60 feet above the ground.
—**A brake** or furling device to stop the unit for repairs.
—**A control panel,** including a device to prevent reverse battery current from driving the windmill during calm periods, and a voltage regulator.
—**A speed-controlling device** to prevent damage in a high wind. Some generators have a variable pitch propellor that is direct-connected to a centrifugal governor to prevent over-speeding. Some use governor flaps. Some have rotors offset from the main support axis to turn them out of the wind at high speeds.
—**Wet cell batteries** to store energy for use during calm periods.
—**DC-AC inverter,** if needed.

Electrical Systems

If total electrical usage is expected to be small, a 12-volt direct current (DC) system permits use of conventional lights and accessories that are readily available at moderate prices. This low voltage has little shock hazard. However, bare wires and the danger of loose terminals do present fire hazards; proper fusing is critical.

A low voltage DC system also can be adapted for partial or limited use of alternating current (AC) equipment. Two-hundred-watt inverters are available from auto supply stores to change 12V DC to 115V AC to operate standard electric razors, radios, or other small appliances.

A 120-volt DC system will permit use of many conventional lights and electrical equipment. Incandescent light circuits may be operated from the 120-volt DC supply. This supply can also handle small kitchen resistance-heating devices, such as coffeemakers and toasters.

Remaining electrical equipment, particularly electronic devices and motors, must be operated from AC circuits connected to the batteries through an inverter. The capacity of this inverter must be equal to the maximum combined power required by the AC appliances. If the inverter is overloaded for even a few seconds, it will burn out, so that a quick burning fuse or quick acting circuit breaker must be used. In selecting the correct inverter size, remember that the starting power required for electric motors is usually two to three times the running power.

Electrical storage capacity can be provided by one or more 12V, heavy duty, lead-acid storage batteries (table 2). Use series or parallel connections when two or more are needed to obtain the voltage and watt-hour storage desired.

Typical Costs (1979)

Small wind generators, up to a maximum rated capacity of 1000 watts, cost about $2 to $3 per maximum rated watt. Larger generators vary from $1 to $2 per rated watt output. A unit rated to deliver a maximum of 2000 watts costs about $3,000, while one with a 6000 watt rating costs $6,000. These costs are for generator only and do not include the tower, batteries, control panel, or 115-volt inverter. These items increase the cost by about $1.20 per rated watt. Typical costs for various additional equipment are listed in table 3.

TABLE 2. Determining storage battery requirements

	Example	Calculations
(a) Determine daily watt-hour needs by multiplying wattage of each lamp or device by hours of expected use.	60-watt kitchen light used 4 hours/day	60 × 4 = 240
	60-watt bath and bedroom lamps (2) used 1 hour/day each	60 × 2 = 120
	30-watt portable TV used 4 hours/day	30 × 4 = 120
	100-watt reading lamp used 3 hours/-day	100 × 3 = 300
	TOTAL, daily watt-hours	780
(b) Divide watt-hours by 12 (volts) to get ampere-hour (AH) need		780 ÷ 12 = 65 AH
(c) Divide calculated AH need by the rated AH of battery to get daily battery capacity requirement	Selected battery, truck-size, 205 AH rating	65 ÷ 205 = .317
(d) Finally, multiply daily battery capacity requirement by probable number of successive calm days. (Three successive days of calm are common. Disregard this factor if backup, gas-powered generator is used in system.)	Estimated 3 calm days	3 × .317 = .951 Or, 1 battery of selected size required.

TABLE 3. Costs for additional equipment

Item	*Approximate cost (dollars)*
Steel tower, per foot	25
Storage batteries:	
Auto, 12-volt, heavy duty, 95 AH	50
Truck, 12-volt, heavy duty, 205 AH	150
Battery service kit and tester	22
Inverter:	
12-volt DC -to- 115V AC-3000 watt, light duty	18
12-volt DC -to- 115V AC-1000 watt, heavy duty	425
Standby generator, heavy duty, 3½ HP gas, 115V AC 1500 watt rated	750

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